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RESEARCH MEMORANDUM

A COMBINED AERODYNAMIC AND GUIDANCE APPROACH FOR A SIMPLE HOMING SYSTEM

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

A COMBINED AERODYNAMIC AND GUIDANCE APPROACH FOR

A SIMPLE HOMING SYSTEM

By Robert A. Gardiner

This paper deals with the study of a system in which simplicity was achieved by eliminating many components. The basic idea of this system involves the use of aerodynamics to help in reducing homing-system complication and aid in increasing missile reliability. By using flicker controls operating directly from the target position as a primary reference, by using the rolling of the missile to scan the seeker field of view, and by using a rotating lift vector, several control system and guidance functions may be eliminated from an air-to-air missile with a corresponding increase in ruggedness and simplicity.

This subject will be described in the following order: the airframe characteristics, the seeker characteristics, and the combined operation of the airframe and seeker necessary to obtain this simplification.

In order to make a realistic analysis of the system, aerodynamic and guidance hardware has been chosen on the basis of availability and simplicity. The airframe, shown in figure 1, is a canard configuration with the front-end (seeker, control system, and control surfaces) bearing mounted free to roll on the aft end. The bearing-mounted front end improves the quality of roll control since roll inertia is reduced and aerodynamic-induced rolling moments are minimized.

The control end of the airframe is shown by the sketch in figure 1. Two of the canard surfaces are used as ailerons, and the other two are used as elevators. The flicker roll control used requires that the ailerons be deflected fully in one direction or the other, while the elevators are fixed at incidence.

The nose design has been influenced by the choice of guidance. A drag-reducing windshield is supported by a tripod in front of a flat pyrex plate-glass window. Behind the window, shown dashed, are the mirror and infrared detector. A lead sulfide cell has been chosen principally because of its ruggedness and adaptability for test purposes. This is followed by the electronic element, containing seven vacuum tubes, and power supply. A pneumatic supply and regulator are in the next section which also contains the aileron actuator.

The seeker used with this system must be capable of detecting targets within a narrow rectangle about 5° long by 1° wide. The elements of this detecting system are boresighted, as shown in figure 2, with the missile axis in such a manner as to aline one end of the detecting rectangle with the axis around which the missile rolls, while the other end is alined in the direction of lift. No gimbals are necessary since pursuit navigation is used.

In operation the airframe and seeker function together as follows: When the missile rolls, the seeker scans a 12° included angle cone with about a 2° central dead zone. Figure 3 illustrates this operation. If a target is located within the active area of this cone, as the missile rolls the detecting area will cross the target and produce a signal. This signal is used to reverse the ailerons causing roll in the opposite direction. This causes the detecting area to recross the target and again reverse the ailerons. Thus, the missile hunts in roll on the target.

As the missile hunts, the flight path of the missile is curved towards the target, since the detecting area and the lift of the airframe are alined to produce this direction of flight-path correction. As the flight path curves, the relative motion between missile and target causes the target to appear to move towards the center end of the seeker rectangle. When the missile is pointed directly towards the target, the target moves into the central dead spot of the seeker, the roll control is inactive, and the missile rolls continually while moving towards the target on an effective straight flight path.

Another way in which the system operation may be described is by use of the block diagram shown in figure 4. The blocks representing roll response, angle-of-attack response, and flight-path response are airframe responses. The optic block and geometry block are guidance functions and represent the seeker and the geometry. The feedback indicated from angle of attack to the optic input occurs since the seeker is fastened to the airframe without gimbals. The primary feedback of geometry and flight path represents the target motion towards the center of the seeker cone. The roll feedback to the optic input illustrates the roll control system and represents the roll hunting action. An input to angle of attack from roll angle is shown and represents the rotating lift vector and illustrates the point that the direction of lift is dependent on the roll angle.

Two modes of operation of the airframe are used to obtain a pursuit chase of the target. During search or during "on target" operation the missile rolls continually while trimmed in a lifting condition. This results in a small-diameter (about 3 ft) helical motion, shown in figure 5, while the missile pursues an effective straight flight path. When flight-path correction is needed, a flicker roll system functions

to point the airframe lift towards the target path and produce the required corrections. The only moving controls are ailerons which are actuated by the flicker roll control operating directly from target position as the primary reference.

When a symmetrical airframe is subjected to combined pitching, yawing, and rolling motion, as is the case with this system, gyroscopic and other coupling between rolling and the other motions can occur. This has been demonstrated by Phillips (ref. 1) and by Nicolaides (ref. 2). The effect of this coupling is shown by a plot of pitch amplitude ratio against roll frequency (fig. 6). For this system the operating point for constant roll and for roll hunting has been kept low to avoid undesirable resonance effects.

To determine the limitations of the system and to get a quick view of the type of operation which could be expected, a one-to-one time-scale simulator was constructed using two moving carts operating on a reduced geometry scale of 30 feet equal to 1 mile. Actual guidance hardware was used on the missile cart shown in figure 7(a). This hardware was mounted on a driving motor chosen to simulate properly the inertia and damping of the airframe in roll. This roll simulator was gimbaled and spring-restrained so that the gimbal inertia, spring, and damping simulated the airframe short-period pitch and yaw oscillation. Two gimbals were used so that both pitch and yaw were represented. The steering gear was directly coupled to the yaw gimbal so that the steering angle was equal to the angle of sideslip.

An automobile headlamp bulb was mounted on the target cart, figure 7(b), to simulate the exhaust of a jet airplane target. The missile cart was accelerated to a speed representing Mach number 1.6 while the target cart ran at a speed representing Mach number 0.8. Various angles of launch, from 0°, directly behind the target, to 45° off the tail of the target, were tried, as well as several launching ranges.

Qualitatively, the nature of the system operation was judged from this simulator and found to be quite satisfactory. However, due to the reduced geometry scale and the physical size of the components, accurate measurements at small ranges could not be made.

In order to provide a more accurate determination a reduced-time-scale simulation was set up using REAC equipment plus an auxiliary nonlinear device to represent the optical system and roll control system.

The REAC was used to represent the airframe and part of the kinematic geometry. The remainder of the geometry, the optical system, and the control system were simulated by a cathode-ray oscilloscope (used to present target position), an optical and photoelectric pickup, and an electromechanical roll simulator.

With this equipment, the missile launching range and angle off the tail of the target to assure a successful flight (a hit) could be determined accurately. These coordinates were obtained for all significant positions in the area surrounding the target. This was found to be divided into a firing area where a hit was always obtained and an area from which a hit is impossible as shown in figure 8.

The useful area is fairly large considering the type of navigation used and almost coincides with the infrared signal cone to be expected from jet aircraft.

It should be noted that this confirms previous work which has been done on pursuit navigation (ref. 3); however, it is believed that the useful firing area is larger than it has generally been thought to be.

From this investigation, it may be concluded that a homing system has been devised which attains simplicity by utilizing several aerodynamic properties of the airframe. The possibility that a similar reduction in complication could be made in the case of other systems should be investigated.

Another conclusion is that a missile using pursuit homing has a useful firing area which may well be large enough to be tactically useful.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 27, 1953.

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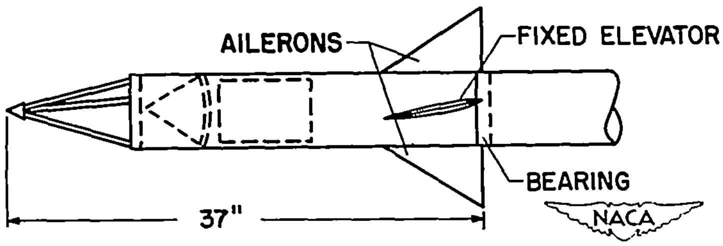
TEST-VEHICLE AIRFRAME



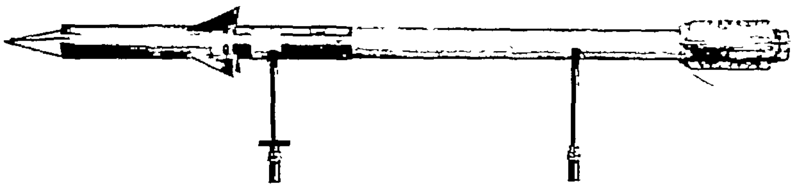


Figure 1

SEEKER BORESIGHTING

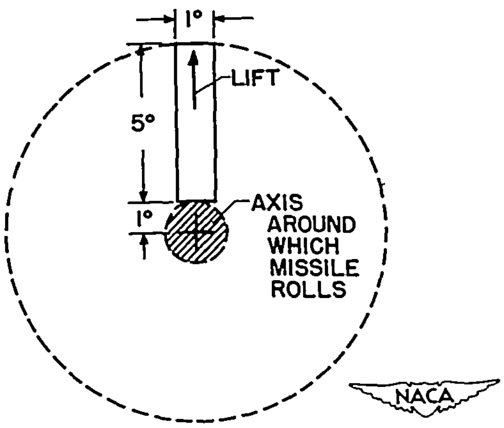


Figure 2

SYSTEM OPERATION

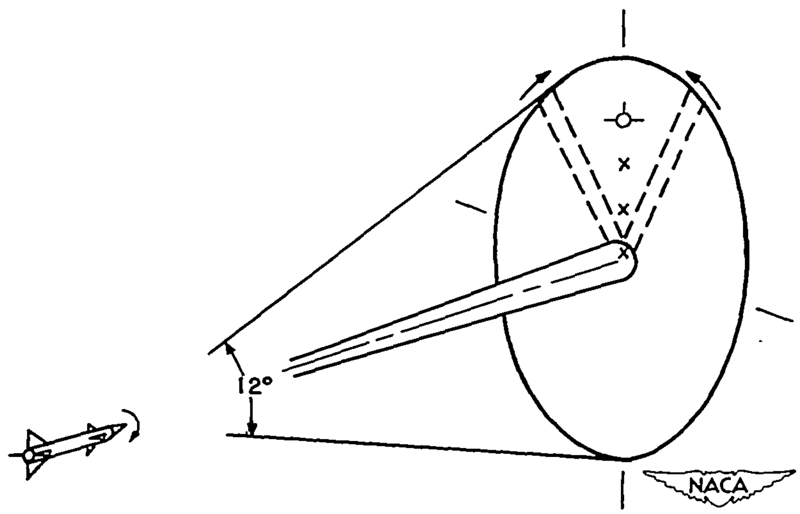


Figure 3

BLOCK DIAGRAM

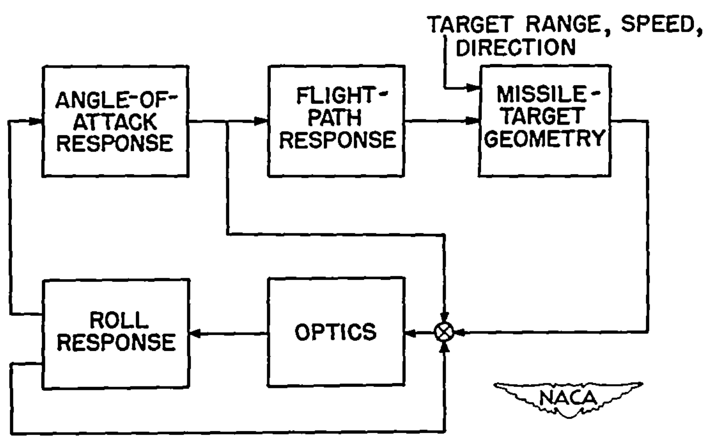


Figure 4

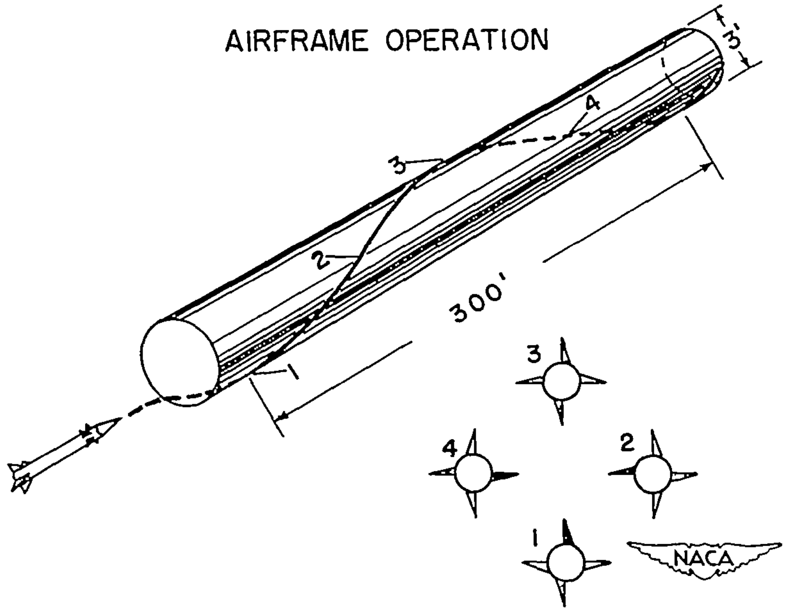


Figure 5

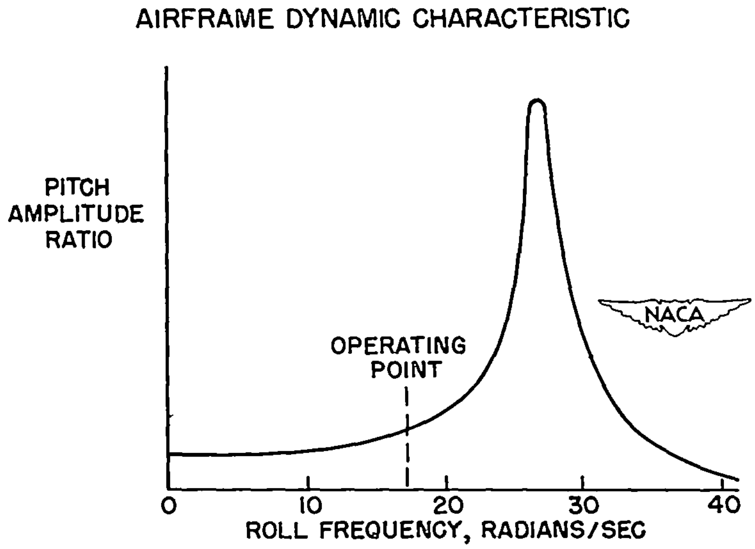


Figure 6

MISSILE CART

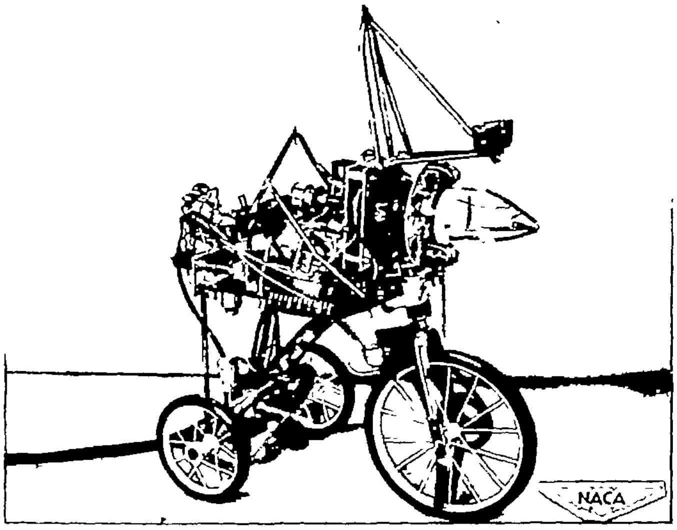


Figure 7(a)

TARGET CART

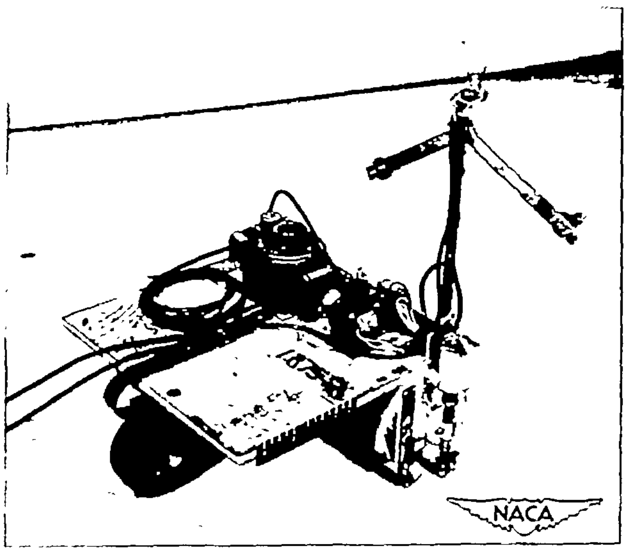


Figure 7(b)

USEFUL FIRING AREA

$V_M/V_T = 2.0$; SEA-LEVEL CONDITIONS

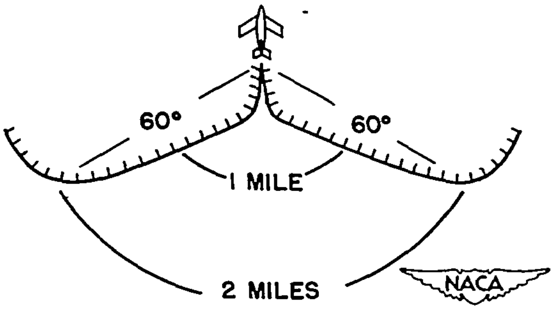


Figure 8